

## C L A I M S

1. An estimation system for estimating an  
2 object state, characterized by comprising:  
3           image input means for inputting an input image  
4 containing an object whose state is to be estimated, the  
5 state being at least one of a position and posture;  
6           3D shape data storage means for storing 3D  
7 shape data of the object;  
8           comparison image generation means for  
9 generating, as a comparison image, an image containing  
10 the object in a predetermined state by using the 3D  
11 shape data stored in said 3D shape data storage means;  
12           image positional relationship detection means  
13 for detecting, for each sub-region having a  
14 predetermined size in the image, a positional  
15 relationship between the input image and the comparison  
16 image generated by said comparison image generation  
17 means;  
18           correction amount calculation means for  
19 calculating a correction amount of the object state in  
20 the comparison image by using the positional  
21 relationship detected by said image positional  
22 relationship detection means; and  
23           state correction means for correcting the  
24 object state set in comparison image generation by said  
25 comparison image generation means by using the  
26 correction amount obtained by said correction amount

27 calculation means, thereby calculating a new object  
28 state.

2. An estimation system for estimating an  
2 object state according to claim 1, characterized by  
3 further comprising state determination means for  
4 determining on the basis of the correction amount  
5 obtained by said correction amount calculation means  
6 whether the object state set by said comparison image  
7 generation means is appropriate,  
8 wherein when it is determined that the object  
9 state is appropriate, the object state set by said  
10 comparison image generation means is output as an  
11 estimation value, and  
12 when it is determined that the object state is  
13 not appropriate, estimation processing including the  
14 comparison image generation processing by said  
15 comparison image generation means, the positional  
16 relationship detection processing by said image  
17 positional relationship detection means, and the  
18 correction amount calculation processing by said  
19 correction amount calculation means is executed again by  
20 setting the new object state calculated by said state  
21 correction means to the predetermined state.

3. An estimation system for estimating an  
2 object state according to claim 2, characterized in that  
3 said state determination means determines that the  
4 object state is appropriate when the correction amount

5 obtained by said correction amount calculation means is  
6 smaller than a predetermined amount, and determines that  
7 the object state is not appropriate when the correction  
8 amount is not smaller than the predetermined amount.

4. An estimation system for estimating an  
2 object state according to claim 2, characterized by  
3 further comprising:

4 first similarity calculation means for  
5 calculating a first similarity between the comparison  
6 image and the input image after the estimation  
7 processing is executed again; and

8 second similarity calculation means for  
9 calculating a second similarity between the comparison  
10 image and the input image before the estimation  
11 processing is executed again,

12 wherein said state determination means  
13 compares the first similarity with the second  
14 similarity, determines that the object state is not  
15 appropriate when the first similarity is higher than the  
16 second similarity, and determines that the object state  
17 is appropriate when the first similarity is not higher  
18 than the second similarity.

5. An estimation system for estimating an  
2 object state according to claim 1, wherein

3 said image input means comprises means for  
4 inputting a moving image containing an object, and

5 said image positional relationship detection

6 means uses a latest frame image of the moving image as  
7 the input image.

6. An estimation system for estimating an  
2 object state according to claim 1, characterized in that  
3 said comparison image generation means comprises:

4 means for reproducing a luminance value of an  
5 object surface, which changes depending on an  
6 illumination condition; and

7 means for generating the comparison image  
8 under an illumination condition close to that for the  
9 input image by using the reproduced luminance value.

7. An estimation system for estimating an  
2 object state according to claim 6, characterized by  
3 further comprising illumination base image group storage  
4 means for storing an illumination base image group  
5 representing a variation in luminance of the object  
6 surface depending on the illumination condition,

7 wherein said comparison image generation means  
8 reproduces the luminance value of the object surface by  
9 using the illumination base image group stored in said  
10 illumination base image group storage means.

8. An estimation system for estimating an  
2 object state according to claim 7, characterized by  
3 further comprising:

4 3D shape measuring means for measuring the 3D  
5 shape data of the object and reflectance data of the  
6 object surface; and

7 illumination base calculation means for  
8 calculating an illumination base image representing the  
9 variation in luminance of the object surface depending  
10 on the illumination condition by using the 3D shape data  
11 and the reflectance data of the object surface which are  
12 measured by said 3D shape measuring means.

9. An estimation system for estimating an  
2 object state according to claim 8, characterized in that  
3 said illumination base calculation means  
4 calculates a vector group representing the luminance  
5 value of each point of the 3D shape data under a  
6 plurality of illumination conditions, obtains a base  
7 vector group in descending order of eigenvalues by  
8 principal component analysis of the vector group, and  
9 outputs the base vector group as the illumination base  
10 image group, and

11 said comparison image generation means  
12 obtains, by using the 3D shape data of the object, a  
13 correspondence between each point of the 3D shape data  
14 of the object and a pixel of the image with the object  
15 being in an estimation value at current time, generates,  
16 by using the correspondence, an image illumination base  
17 group in which the illumination base image group is  
18 projected to the image with the object being in the  
19 estimation value, and generates, as the comparison  
20 image, an image nearest to the input image by linear  
21 connection of the image illumination base group.

10. An estimation system for estimating an  
2 object state according to claim 1, characterized in that  
3 said correction amount calculation means calculates, as  
4 the correction amount, a 3D motion of the object which  
5 causes a moving amount of an object part corresponding  
6 to each sub-region in the comparison image to be near to  
7 an image displacement distribution by using the 3D shape  
8 data of the object and the image displacement  
9 distribution representing the positional relationship  
10 between the comparison image and the input image for  
11 each sub-region.

11. An estimation system for estimating an  
2 object state according to claim 1, characterized by  
3 further comprising feature extraction means for  
4 extracting an image feature amount of each of the input  
5 image and comparison image on the basis of luminance  
6 values of the input image and the comparison image  
7 generated by said comparison image generation means,  
8 wherein said image positional relationship  
9 detection means detects the positional relationship  
10 between the input image and the comparison image for  
11 each sub-region on the basis of the image feature amount  
12 extracted by said feature extraction means.

12. An estimation method of estimating an  
2 object state, characterized by comprising the steps of:  
3 inputting an input image containing an object  
4 whose state is to be estimated, the state being at least

5 one of a position and posture;  
6 generating, as a comparison image, an image  
7 containing the object in a predetermined state by using  
8 3D shape data of the object;  
9 detecting a positional relationship between  
10 the comparison image and the input image for each  
11 sub-region having a predetermined size in the image;  
12 calculating a correction amount of the object  
13 state in the comparison image by using the detected  
14 positional relationship; and  
15 correcting the object state set in comparison  
16 image generation by using the calculated correction  
17 amount, thereby calculating a new object state.

13. An estimation method of estimating an  
2 object state according to claim 12, characterized by  
3 further comprising the steps of:  
4 determining on the basis of the calculated  
5 correction amount whether the object state set in  
6 comparison image generation is appropriate; and  
7 outputting the object state set in comparison  
8 image generation as an estimation value when it is  
9 determined that the object state is appropriate,  
10 wherein when it is determined that the object  
11 state is not appropriate, estimation processing  
12 including the step of generating the comparison image,  
13 the step of detecting the positional relationship, and  
14 the step of calculating the correction amount is

15   executed again by setting the calculated new object  
16   state to the predetermined state.

14.   An estimation method of estimating an  
2   object state according to claim 13, characterized in  
3   that in the determination step, it is determined that  
4   the object state is appropriate when the correction  
5   amount is smaller than a predetermined amount, and it is  
6   determined that the object state is not appropriate when  
7   the correction amount is not smaller than the  
8   predetermined amount.

15.   An estimation method of estimating an  
2   object state according to claim 13, characterized by  
3   further comprising the steps of:  
4         calculating a first similarity between the  
5   comparison image and the input image after the  
6   estimation processing is executed again; and  
7         calculating a second similarity between the  
8   comparison image and the input image before the  
9   estimation processing is executed again,  
10        wherein in the determination step, the first  
11   similarity is compared with the second similarity, it is  
12   determined that the object state is not appropriate when  
13   the first similarity is higher than the second  
14   similarity, and it is determined that the object state  
15   is appropriate when the first similarity is not higher  
16   than the second similarity.

16.   An estimation method of estimating an



2 object state according to claim 12, wherein  
3 in the step of inputting the image, a moving  
4 image containing an object is input, and  
5 in the step of detecting the positional  
6 relationship, a latest frame image of the moving image  
7 is used as the input image.

17. An estimation method of estimating an  
2 object state according to claim 12, characterized in  
3 that the step of generating the comparison image  
4 comprises the steps of:  
5 reproducing a luminance value of an object  
6 surface, which changes depending on an illumination  
7 condition; and  
8 generating the comparison image under an  
9 illumination condition close to that for the input image  
10 by using the reproduced luminance value.

18. An estimation method of estimating an  
2 object state according to claim 17, characterized in  
3 that in the step of generating the comparison image, the  
4 luminance value of the object surface is reproduced by  
5 using an illumination base image group representing a  
6 variation in luminance of the object surface depending  
7 on the illumination condition.

19. An estimation method of estimating an  
2 object state according to claim 18, characterized by  
3 further comprising the steps of:  
4 measuring the 3D shape data of the object and

5 reflectance data of the object surface; and  
6 calculating an illumination base image  
7 representing the variation in luminance of the object  
8 surface depending on the illumination condition by using  
9 the 3D shape data and the reflectance data of the object  
10 surface.

20. An estimation method of estimating an  
2 object state according to claim 19, characterized in  
3 that  
4 in the step of calculating the illumination  
5 base image, a vector group representing the luminance  
6 value of each point of the 3D shape data under a  
7 plurality of illumination conditions is calculated, a  
8 base vector group is obtained in descending order of  
9 eigenvalues by principal component analysis of the  
10 vector group, and the base vector group is output as the  
11 illumination base image group, and  
12 in the step of generating the comparison  
13 image, a correspondence between each point of the 3D  
14 shape data of the object and a pixel of the image with  
15 the object being in an estimation value at current time  
16 is obtained by using the 3D shape data of the object, an  
17 image illumination base group in which the illumination  
18 base image group is projected to the image with the  
19 object being in the estimation value is generated by  
20 using the correspondence, and an image nearest to the  
21 input image is generated as the comparison image by

22 linear connection of the image illumination base group.

21. An estimation method of estimating an  
2 object state according to claim 12, characterized in  
3 that in the step of calculating the correction amount, a  
4 3D motion of the object which causes a moving amount of  
5 an object part corresponding to each sub-region in the  
6 comparison image to be near to an image displacement  
7 distribution is calculated as the correction amount by  
8 using the 3D shape data of the object and the image  
9 displacement distribution representing the positional  
10 relationship between the comparison image and the input  
11 image for each sub-region.

22. An estimation method of estimating an  
2 object state according to claim 12, characterized by  
3 further comprising the step of extracting an image  
4 feature amount of each of the comparison image and input  
5 image on the basis of luminance values of the comparison  
6 image and input image,

7 wherein in the step of detecting the  
8 positional relationship, the positional relationship  
9 between the input image and the comparison image for  
10 each sub-region is detected on the basis of the image  
11 feature amount.

23. An estimation program for estimating an  
2 object state, which causes a computer to execute the  
3 steps of:

4 inputting an input image containing an object

5 whose state is to be estimated, the state being at least  
6 one of a position and posture;  
7           generating, as a comparison image, an image  
8 containing the object in a predetermined state by using  
9 3D shape data of the object;  
10           detecting a positional relationship between  
11 the comparison image and the input image for each  
12 sub-region having a predetermined size in the image;  
13           calculating a correction amount of the object  
14 state in the comparison image by using the detected  
15 positional relationship; and  
16           correcting the object state set in comparison  
17 image generation by using the calculated correction  
18 amount, thereby calculating a new object state.

24. An estimation program for estimating an  
2 object state according to claim 23, which causes the  
3 computer to further execute the steps of:  
4           determining on the basis of the calculated  
5 correction amount whether the object state set in  
6 comparison image generation is appropriate;  
7           outputting the object state set in comparison  
8 image generation as an estimation value when it is  
9 determined that the object state is appropriate; and  
10           executing again estimation processing  
11 including the step of generating the comparison image,  
12 the step of detecting the positional relationship, and  
13 the step of calculating the correction amount by setting

14 the calculated new object state to the predetermined  
15 state when it is determined that the object state is not  
16 appropriate.

25. An estimation program for estimating an  
2 object state according to claim 24, which causes the  
3 computer to execute, as the determination step, the step  
4 of determining that the object state is appropriate when  
5 the correction amount is smaller than a predetermined  
6 amount, and determining that the object state is not  
7 appropriate when the correction amount is not smaller  
8 than the predetermined amount.

26. An estimation program for estimating an  
2 object state according to claim 24, which causes the  
3 computer to further execute:

4 the step of calculating a first similarity  
5 between the comparison image and the input image after  
6 the estimation processing is executed again;

7 the step of calculating a second similarity  
8 between the comparison image and the input image before  
9 the estimation processing is executed again; and

10 as the determination step, the step of  
11 comparing the first similarity with the second  
12 similarity, determining that the object state is not  
13 appropriate when the first similarity is higher than the  
14 second similarity, and determining that the object state  
15 is appropriate when the first similarity is not higher  
16 than the second similarity.

27. An estimation program for estimating an  
2 object state according to claim 23, which causes the  
3 computer to execute:  
4 as the step of inputting the image, the step  
5 of inputting a moving image containing an object; and  
6 as the step of detecting the positional  
7 relationship, the step of using a latest frame image of  
8 the moving image as the input image.

28. An estimation program for estimating an  
2 object state according to claim 23, which causes the  
3 computer to execute, in the step of generating the  
4 comparison image, the steps of:  
5 reproducing a luminance value of an object  
6 surface, which changes depending on an illumination  
7 condition; and  
8 generating the comparison image under an  
9 illumination condition close to that for the input image  
10 by using the reproduced luminance value.

29. An estimation program for estimating an  
2 object state according to claim 28, which causes the  
3 computer to execute, as the step of generating the  
4 comparison image, the step of reproducing the luminance  
5 value of the object surface by using an illumination  
6 base image group representing a variation in luminance  
7 of the object surface depending on the illumination  
8 condition.

30. An estimation program for estimating an

2 object state according to claim 29, which causes the  
3 computer to further execute the steps of:  
4           measuring the 3D shape data of the object and  
5 reflectance data of the object surface; and  
6           calculating an illumination base image  
7 representing the variation in luminance of the object  
8 surface depending on the illumination condition by using  
9 the 3D shape data and the reflectance data of the object  
10 surface.

31. An estimation program for estimating an  
2 object state according to claim 30, which causes the  
3 computer to execute:  
4           as the step of calculating the illumination  
5 base image, the step of calculating a vector group  
6 representing the luminance value of each point of the 3D  
7 shape data under a plurality of illumination conditions,  
8 obtaining a base vector group in descending order of  
9 eigenvalues by principal component analysis of the  
10 vector group, and outputting the base vector group as  
11 the illumination base image group, and  
12           as the step of generating the comparison  
13 image, the step of obtaining a correspondence between  
14 each point of the 3D shape data of the object and a  
15 pixel of the image with the object being in an  
16 estimation value at current time by using the 3D shape  
17 data of the object, generating an image illumination  
18 base group in which the illumination base image group is

19 projected to the image with the object being in the  
20 estimation value by using the correspondence, and  
21 generating, as the comparison image, an image nearest to  
22 the input image by linear connection of the image  
23 illumination base group.

32. An estimation program for estimating an  
2 object state according to claim 23, which causes the  
3 computer to execute, as the step of calculating the  
4 correction amount, the step of calculating, as the  
5 correction amount, a 3D motion of the object which  
6 causes a moving amount of an object part corresponding  
7 to each sub-region in the comparison image to be near to  
8 an image displacement distribution by using the 3D shape  
9 data of the object and the image displacement  
10 distribution representing the positional relationship  
11 between the comparison image and the input image for  
12 each sub-region.

33. An estimation program for estimating an  
2 object state according to claim 23, which causes the  
3 computer to further execute:  
4 the step of extracting an image feature amount  
5 of each of the comparison image and input image on the  
6 basis of luminance values of the comparison image and  
7 input image; and  
8 as the step of detecting the positional  
9 relationship, the step of detecting the positional  
10 relationship between the input image and the comparison



- 11 image for each sub-region on the basis of the image
- 12 feature amount.